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THE UTILITY OF PHOSPHORESCENCE IN DEEP-SEA ANIMALS.

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IN a paper entitled "The Color of Deep-Sea Animals," read at the last meeting of the Iowa Academy of Sciences, I brought together a number of facts tending to show that the actual quantity of phosphorescent light emitted by animals of the deep sea was very considerable; so great, indeed, as to supply over definite areas of the sea bottom a sufficient illumination to render visible the colors of the animals themselves. If this be true, we have an explanation of the colors themselves along the same lines as are adopted in discussions of animal coloration in general. Coloration is practically meaningless in the absence of sufficient light to make colors visible. Having explained the colors of deep-sea forms by demonstrating a light in the depths sufficient to render visible the prevailing bright colors, *i.e.*, reds, yellows, and greens, of the animal inhabitants, it is interesting, and may be profitable, to seek an answer to the question: "Of what profit is the phosphorescence to its possessors?"

I must confess to having scant sympathy with those naturalists who delight in demonstrating, to themselves at least, the falsity of the good old Darwinian dictum that "every character possessed by an animal is of use to the species, or was of use to its ancestors." Men nowadays are willing to assert boldly that certain characters of animals are "meaningless."

For instance, Beddard, in his *Animal Coloration*, p. 37, says: "The inevitable conclusion, therefore, from these facts appears to be that the brilliant and varied colorations of deep-sea animals are totally devoid of meaning. They cannot be of advantage for protective purposes, or as warning colors, for the single and sufficient reason that they are invisible."

Again, one of our own writers, Dr. Walter Faxon, in his work on the stalk-eyed Crustacea secured by the *Albatross* (p. 253), says, in reference to the red color of the deep-sea Crustacea: "This color, then, is to be regarded as entirely useless to its possessor," and concludes that because certain species turn red when placed in the dark, he can explain the red color of deep-sea forms as a purely physical result of their environment.

Now I, for one, am unwilling to surrender the original Darwinian proposition. Of course there are many things yet to be explained, or even inexplicable with our present knowledge. But this does not justify the unqualified use of such terms as "meaningless" and "useless."

It is the purpose of this paper to explain cases in which phosphorescent light is emitted by animals, in terms of its use to the animals themselves.

To this end we can conveniently divide the inhabitants of deep water into *free-swimming* and *fixed* forms. In the former class would be all of the fishes, nearly all of the Crustacea, most Mollusca, Vermes, and Echinodermata, part of the Cœlenterata, and most of the Protozoa.

It will also simplify matters to remember that practically all deep-sea forms live on animal food. Among the fishes are several, allied to *Lophius* and *Antennarius*, which are provided with a bait said to be luminous, which serves to attract the prey. Others are luminous along the lateral line in definite spots. The utility in this case is not certainly known, but two suggestions may be made, one to the effect that the light attracts the mate and thus serves the purpose of *attractive coloration*; the other that it attracts the prey and serves the purpose of *alluring coloration*.

A very large number of crustaceans are phosphorescent, often brilliantly so. Many of these have large eyes, and are particularly active in movement and voracious in appetite. They feed on minute organisms, for the most part, and it can hardly be doubted that they often use their phosphorescent powers for the purpose of illuminating their surroundings and revealing their prey. Here again it is probable that the

strangely attractive power of light serves a definite purpose in the life economy of the animal.

Among the Mollusca we have few instances, so far as I know, of phosphorescent organs. Lamellibranchs, however, are largely vegetative, impassive animals. The Gastropoda are more active, but still slow in movement compared with most animals. Among the Cephalopoda are a number of highly specialized and swift-moving forms, and here, if anywhere among mollusks, we should expect to find phosphorescent organs. At the Detroit meeting of the American Association, Professor William E. Hoyle, of England, read an exceedingly interesting paper on certain organs possessed by Cephalopoda secured by the *Challenger*. These organs were regarded as phosphorescent by Professor Hoyle, who described a highly specialized apparatus designed to reflect light from the phosphorescent bodies downward to the bottom over which the animal passed. In this case it appears that there is not only a light, but also a reflector, an efficient "bull's-eye" lantern for use in hunting through the abyssal darkness. Among Vermes are many forms possessing a high degree of light-emitting power, which may be either attractive, alluring, or directive in function, and thus of direct advantage to its possessors.

Most of the echinoderms, although not truly fixed, are not capable of rapid locomotion. Perhaps the most active animals of this group are the serpent stars, some of which are able not only to crawl rapidly, but actually to swim with considerable facility. It is therefore interesting to note that the only phosphorescent echinoderm that I can find any account of belongs to the Ophiuridæ, and is described by Agassiz as "exceedingly phosphorescent, emitting at the joints along the whole length of its arms a bright, bluish-green light." Its utility can only be conjectured. If, as in the case with many of its allies, its life is spent crawling among the branches of phosphorescent gorgonians, the protection thus secured would certainly be advantageous.

Coming now to the Cœlenterata, we find many notably phosphorescent organisms. The ctenophores and medusæ comprise the greater part of the free-swimming members of this

subkingdom, and it is among these that we encounter amazing displays of the "living light." The most brilliant exhibition of phosphorescence that I have seen was caused by immense numbers of ctenophores in Bahia Honda, Cuba. The animals kept in a compact body and produced a maze of intertwining circles of vivid light. These animals have so-called "eye-spots" and seem to be able to distinguish light. The phosphorescence may serve to keep them together, and thus effect the same end as "directive coloration" among vertebrates and insects.

It is worth noting that blind species of groups normally possessed of eyes are seldom if ever phosphorescent, a fact that seems further to enforce the idea that phosphorescence is used in connection with the power of vision, and probably serves as an aid thereto.

Although Noctiluca and other allied phosphorescent Protozoa are more properly pelagic than deep-sea forms, they may occur at considerable depths, and thus come within the province of this discussion. These differ from the organisms hitherto mentioned in that they have no recognized organs of sight, and, further, in their extreme simplicity of organization. Like most if not all Protozoa, they occur in enormous swarms and have some means of keeping together, as is necessary in the case of all forms that conjugate as a preliminary to reproduction, as do the ones under discussion. They are propelled by flagella and appear to control their own movements. At first thought one is at a loss to explain the phosphorescence of these eyeless free-swimming forms, but a little reflection will show a probable explanation. Although eyeless, many Protozoa have been proved to be sensitive to light, both natural and artificial. Any one who has worked with these lowly forms has noticed that each species has a preference for either the light or the dark side of the jar in which it is confined. Indeed it is practically certain that sensibility to light is a fundamental property of simple protoplasm. This being true, it is easy to conceive of the phosphorescence of Noctiluca and its allies as *directive* in function, thus aiding them in finding each other for the purpose of conjugation and the perpetuation of their kind.

This same explanation may be applied to many of the phos-

phorescent medusæ. In the subtropical Atlantic hundreds of square miles of the surface are thickly strewn with a medusa, *Linerger mercurius*, which glows like a living coal at night. This species has eight marginal sense-bodies, and the phosphorescence may well serve as a directive contrivance, aiding in the perpetuation of the species.

In general, it may be said that the phosphorescent powers possessed by free-swimming deep-sea forms can be accounted for in very much the same manner as their coloration, and serve much the same purposes as protective, aggressive, alluring, and directive colorations.

We now come to a consideration of the uses of phosphorescent powers in the second class of animals indicated at the beginning of this paper, namely, the *fixed forms*.

Most of the phosphorescent organisms in this group belong to the subkingdom Cœlenterata. Among the Actinozoa the Pennatulidæ are mentioned by several writers as being especially brilliant in their flashes of light. The gorgonians are also often phosphorescent, and Agassiz says: "Species living beyond 100 fathoms may dwell in total darkness, and be illuminated at times merely by the movements of abyssal fishes through the forests of phosphorescent alcyonarians."

Many authors have noted the light-emitting powers of numerous hydroids. These occur in great quantities over certain areas of the sea bottom, and must add considerably to the sum total of deep-sea light.

It may, I think, be said that in general the fixed marine forms are not behind their free-swimming allies in either the quality or quantity of their light-producing powers.

The question now before us is: "Of what use is this power to its fixed and sightless possessors?"

Perhaps the most generally accepted opinion is that suggested by Verrill, who regards the phosphorescence as *protective* in function. Most Cœlenterata, he argues, are possessed of nematocysts. Fishes are known in some instances to eat the polyps of colonial forms, and they might come to associate the phosphorescence with the nettling cells, and thereafter avoid those forms showing the danger signal.

It is somewhat unfortunate for this argument that few if any of the fixed *Cœlenterata* that are remarkable for their phosphorescence possess nematocysts that are likely to be regarded by a hungry fish as at all formidable. The *Gorgonidæ*, *Antipathidæ*, *Alcyonidæ*, and *Pennatulidæ*, all notably phosphorescent, are almost if not quite destitute of nematocysts. As for the *Hydroida*, there is only one known species, so far as I can learn, whose nematocysts can be felt at all by the human skin. *Millepora*, if it be a hydroid, is of course another exception.

Neither is it likely that the phosphorescence of these fixed forms serves the same purpose as attractive coloration. Although the *Cœlenterata* are, in general, bisexual, the spermatozoa are shed into the water to find their way as best they can to the female element in other colonies. So far as I know, the colonies of both sexes are phosphorescent, but the light, in the hydroids at least, seems to be mainly confined to the polyps, or nonsexual "persons," excepting in those forms that produce medusæ.

Having shown that the phosphorescence of fixed forms cannot be regarded as protective, and that it does not appear to be for the purpose of attracting or guiding the sexes in coming together, we turn to a third and more promising explanation.

The food of the fixed *Cœlenterata* consists mainly of either Crustacea of the smaller sorts, their embryos, the Protozoa, or the unicellular plants, such as diatoms.

Most of the minute Crustacea have effective eyes, and it has been repeatedly demonstrated that they are attracted by light, both artificial and natural. Crustacean embryos usually have eyes that are very large in proportion. In many cases these, too, are attracted by light. Although I know of no direct experiments being made with phosphorescent light, it is reasonable to suppose that it would affect them in a like manner, although probably in a less degree. If this is true, the phosphorescent powers of the fixed *Cœlenterata* would cause the small crustaceans, and more surely their embryos, to congregate near the illuminated areas, and thus be captured. This is on the same principle that many fishes, birds, and even mammals

are secured by what is known as "fire hunting." In this same way the entomologist reaps a harvest by the aid of the electric light. The process would be analogous, perhaps, to what is known as "alluring coloration," and its function in decoying prey. The phosphorescence would thus be of direct utility to the fixed *coelenterates* in securing crustacean food.

We may, I think, still further extend the application of this idea so as to include the attraction of *Protozoa* and even *diatoms*. As already remarked, both of these groups of organisms contain many species that are strongly attracted by light, which appears to act as a direct stimulus to both unicellular animals and plants by virtue of its well-known effect on protoplasm itself.

We thus see that all of the more important organisms upon which fixed *coelenterates* feed are likely to be attracted by light, and it is reasonable to assume that phosphorescent light affects them in this manner.

This, then, is the hypothetical explanation by which we may explain the possession of phosphorescent light by so many fixed *Coelenterata* on the old Darwinian principle of direct benefit to its possessors, the benefit being the aid rendered in securing food.